Elastic distribution of Microshutters, measurements obtainable on James Web Space Telescope

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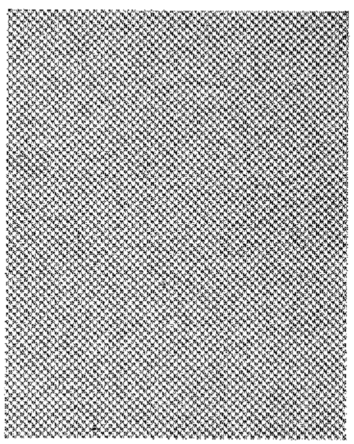
Microshutters for James Web Space Telescope (JWST)

Spectrographic astronomy measurements in the near-infrared region[1,2,3] will be done by functional two-dimensional micro-shutter arrays that are being fabricated at the NASA Goddard Space Flight Center for the James Webb Space Telescope (JWST). These micro-shutter arrays will represent the first mission-critical MEMS devices to be flown in space. JWST will use microshutter arrays to select focal plane object. 2-D programmable aperture masks of more than 200,000 elements select such space object. The use of silicon wafer material promises high efficiency and high contrast. Microshutter operation temperature is around 35K. Microshutter arrays are fabricated as close-packed silicon nitride membranes with a unit cell size of 105 x 204 µm. A layer of magnetic material is deposited onto each shutter. Individual shutters are equipped with a torsion flexure. Reactive ion etching (RIE) releases the shutters so they can open up to 90 degrees using the torsion flexure. Shutter rotation is initiated into a silicon support structure via an external magnetic field. Two electrically independent aluminum electrodes are deposited, one onto each shutter and another onto the support structure side-wall, permitting electrostatic latching and 2-D addressing to hold specific shutters open via external electronics (See Figure 1)

[1] S.H. Moseley, et al., Status of the Development of 128x128 Microshutter Array, in MOEMS and Miniaturized Systems, Proceedings of SPIE 4178, 2000.
[2] M.J. Li, et al., Fabrication of Microshutter Arrays for Space Applications, in MEMS Design, Fabrication, Characterization, and Packaging, Proceedings of SPIE 4407, 2001
[3] T.T. King, G. Kletetschka, et al., Cryogenic characterization and testing of magnetically actuated microshutter arrays for the James Webb Space Telescope. Journal of Micromechanics and Microengineering, 15, 1594-1606, 2005



Q137 OPEN by magnetic field 400 mT 11/14/2008.
Failed closed RT: 85 (0.1362%); Partial fail closed RT: 17 (0.0272%)

Figure 1: Magnetically actuated microshutter array show distribution of the shutters that did not open among the once that did open. Similar distributions will be used when taking the images with JWST. Our analysis indicates that distributions of the closed shutters are indicator of the variable bowing of the microshutter membranes that translates into the elastic repulsion from the walls acting against the electrostatic forces.

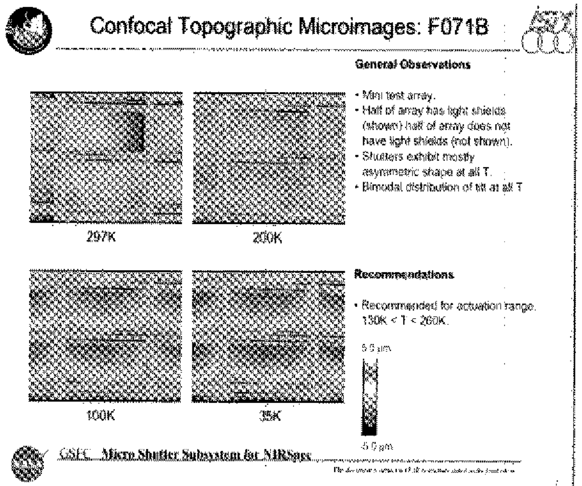


Figure 2: Confocal microscopy allows taking images of the microshutters at variable temperatures while preserving information about the topography. This way the microshutters can be analyzed for the degree of shape change during the cooling.

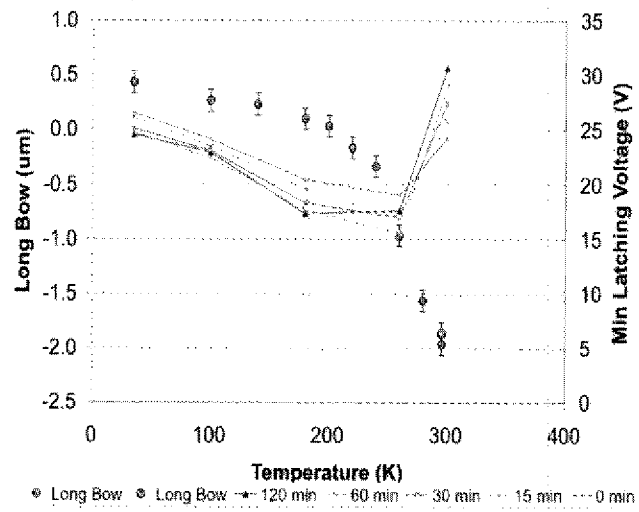
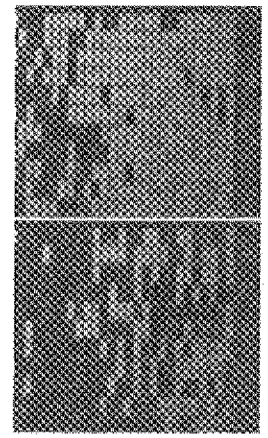


Figure 3: Diagram shows the temperature effect on the minimum voltage release of latched microshutters. We also included effect of length of time used to hold microshutters open (0-120 minutes)



• Latch all shutters at test voltage
• Decrement voltage, counting the number of shutters that close at each voltage
• Use results to determine the average release voltage of the array

Figure 4: Test setup for measuring the minimum voltage release included a dewar containing a window that allowed observation of the microshutters while they were released at the minimum voltage. Images above were taken by camera observing microshutters in this windows while they were near liquid helium temperature.

Discussion:

Figure 3 indicates a direct correlation between the minimum voltages and degree of bowing. Data also show that the degree of bowing can be detected with larger precision if microshutters are held longer time in latched state. The maximum time was 2 hours and is comparable with exposure times that will be used on James Web Space Telescope. We believe that the minimum voltage release measurements can be used to investigate any change of the degree of bowing as a result of exposure to the space environment during the life span of the JWST mission.

Acknowledgements:

The minimum release voltage measurements were done by summer intern, John Yamrick and his advisor, James C. M. Hwang, Ph.D. Professor of Electrical Engineering, Director of Compound Semiconductor Technology Laboratory, Lehigh University. The work was also supported by Bob Silverberg and Stephanie Getty.

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